RHIC Operations in FY24 - FY25

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2024 APEX Workshop

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Outline

Mission Support and the Long-Range Plans

Performance of the FY23 RHIC Run

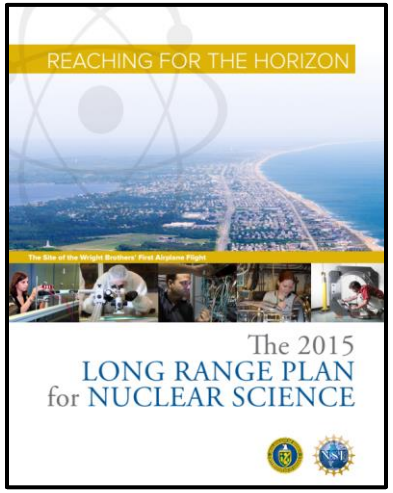
Completing the RHIC Physics Science Mission in FY24 and FY25

Performance Improvements for FY24, FY25 and Beyond

Summary and Outlook

Mission Support and the Long-Range Plans

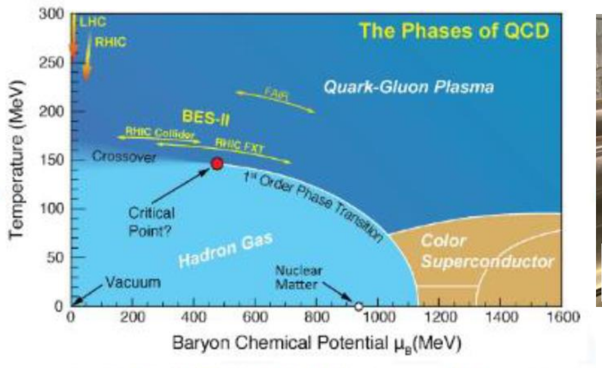
Long Range Plans for Nuclear Science

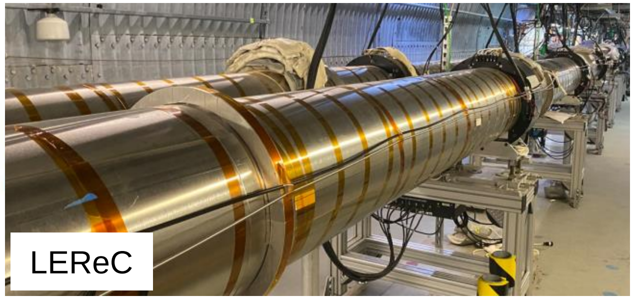


2015 LRP

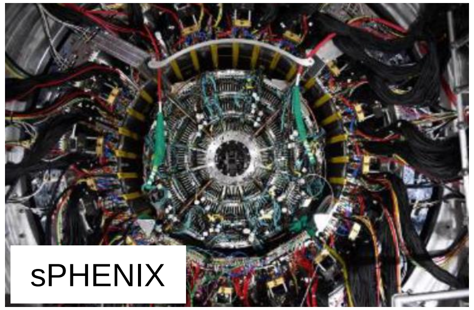
<u>Recommendation #1</u>: The highest priority in this 2015 plan: to capitalize on the investments made; states the two central goals of measurements planned at RHIC:
1) probe the inner workings of QGP by resolving its properties at shorter and shorter length scales…
2) map the phase diagram of QCD …

<u>Recommendation #3</u>: "… a high-energy high-luminosity polarized EIC as the highest priority for new facility construction …"

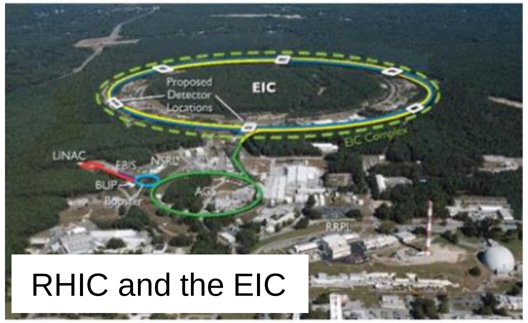




STAR Beam Energy Scan with LEReC completed



construction and installation completed, commissioning in Run-23



BNL selected as host site, CD-3A review in Nov 2023

2023 LRP

<u>Recommendation #1</u>: … continued effective operation of national user facilities …. and completing the RHIC science program…

<u>Recommendation #3</u>: Expeditious completion of the EIC as the highest priority for facility construction

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Performance of the FY23 RHIC Run

RHIC Run-23 – priority sPHENIX commissioning

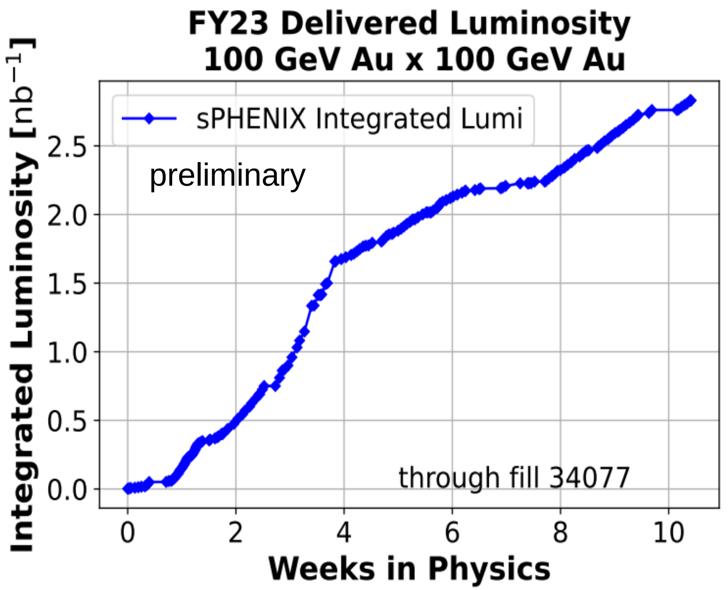
Run Coordinator
Travis Shrey

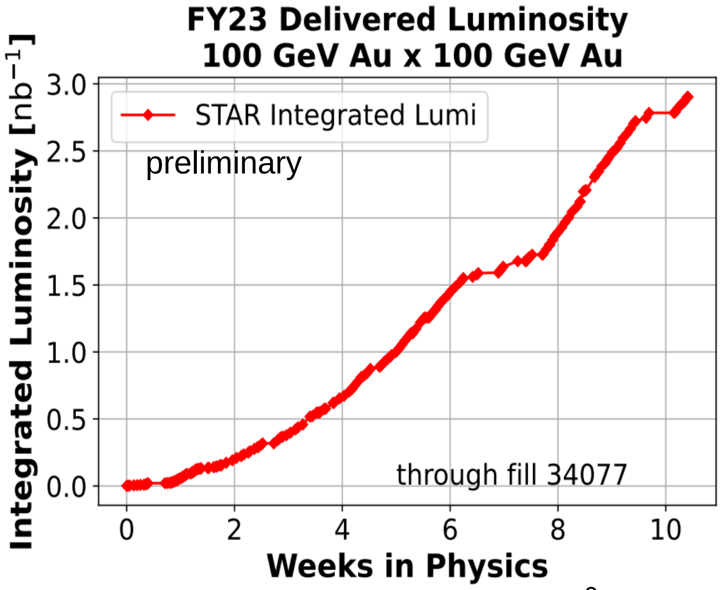
Timeline for sPHENIX commissioning with Au+Au (100 GeV/beam)

• sPHENIX magnet mapping complete	10 Nov 2022
• sPHENIX MIE PD-4 project approval	12 Dec 2022
• RHIC 4K cooldown	5 May 2023
• first beam injection	8 May 2023 (Blue), 10 May 2023 (Yellow)
• sPHENIX approval to operate	18 May 2023
• sPHENIX commissioning with beam	18 May 2023
• STAR physics “declared”	20 May 2023
• APEX and maintenance	starting 24 May 2023 (alternating weeks)
• sPHENIX magnet on at full field	31 May 2023
• Blue Ring 1004B valve box failure	1 August 2023
• end of RHIC Run 2023	4 August 2023

Achievements

- Provided wide variety of RHIC beam conditions (number of bunches, bunch intensities, up to 2 mrad crossing angles).
- Provided collisions also for STAR with 1 mrad crossing angle and luminosity-leveling; ~30% of minimum-bias goal (Run23+25) collected.
- Met sPHENIX commissioning requirements per sPHENIX schedule.





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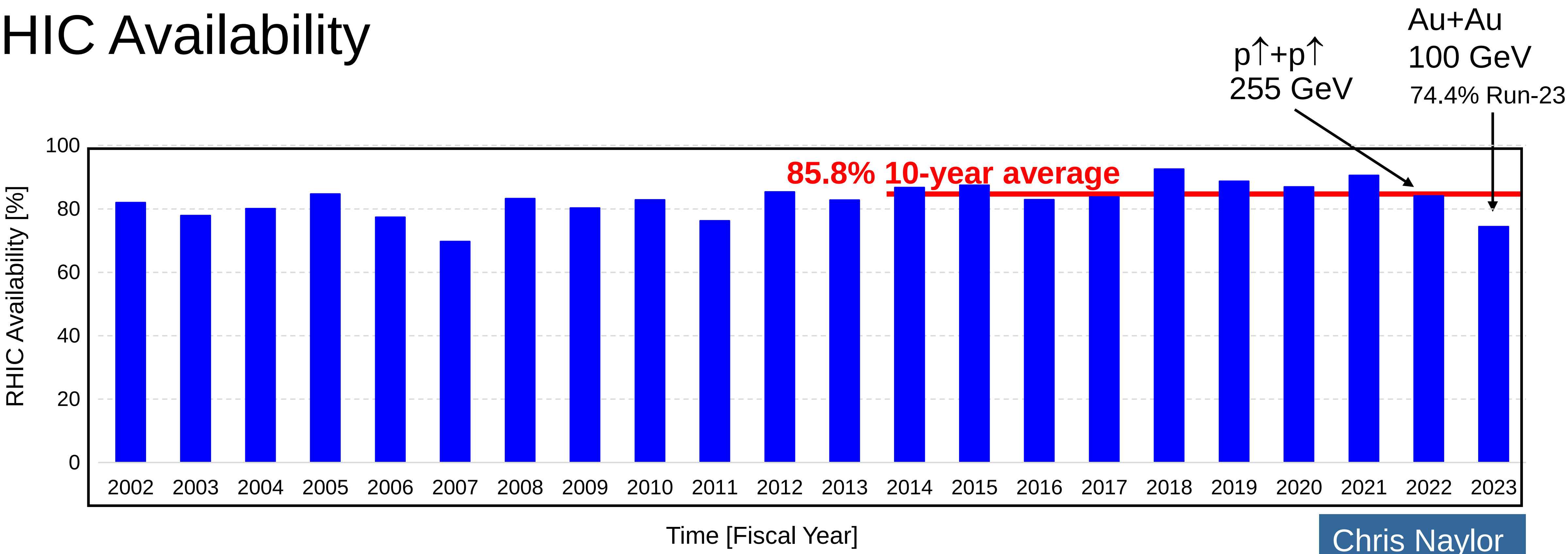
RHIC Availability



Chris Naylor

Availability = beam time / scheduled beam time (denominator excludes scheduled maintenance)

Availability goals: 82.5% < FY20,
85% FY21-FY22
82.5% FY23

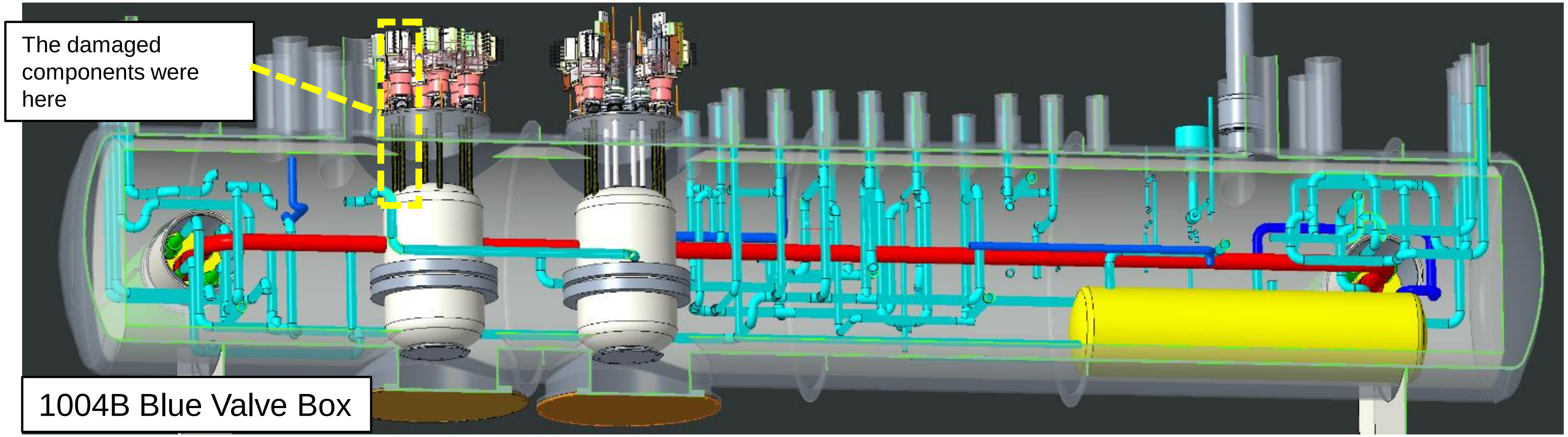
Availability was impacted by operation during the summer months (mitigation measures in backup slides), Conduct of Operations compliance and - to some extent - staffing changes.

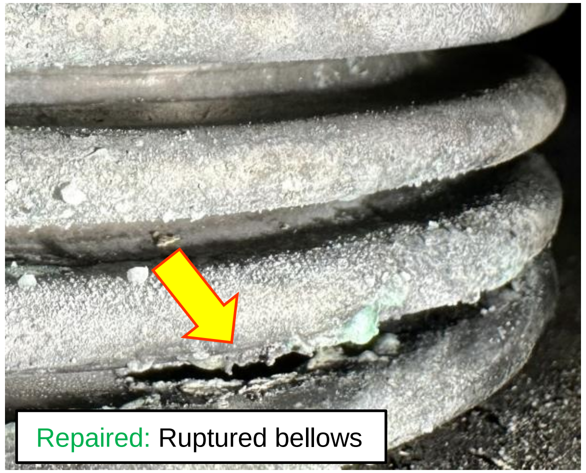
Availability goal for FY24: 82.5%

RHIC Recovery

Russ Feder,
Chaofeng Mi,
John Escallier et al

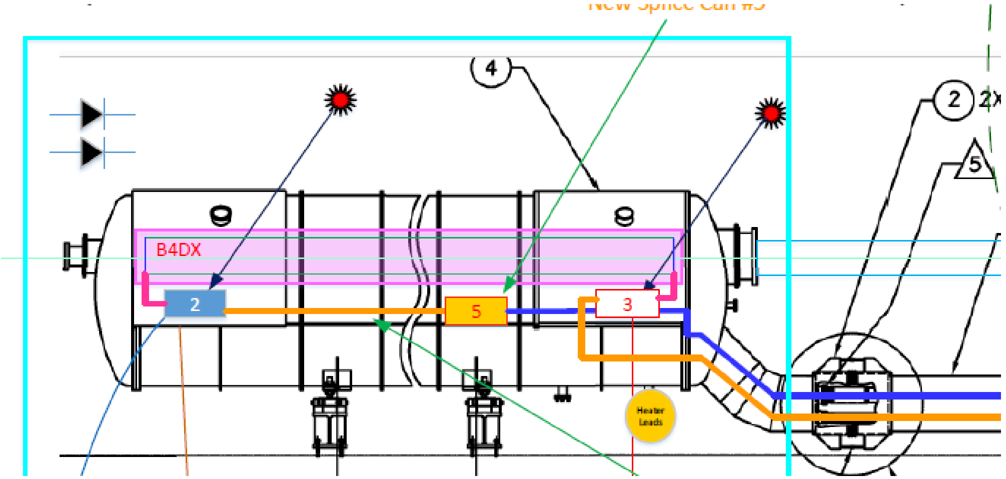
Failure of a magnet power supply 150A current lead in 1004B blue valve box (Aug 2023)
External review of causal analysis and engineering solutions (Nov 2023) https://indico.bnl.gov/event/20923/



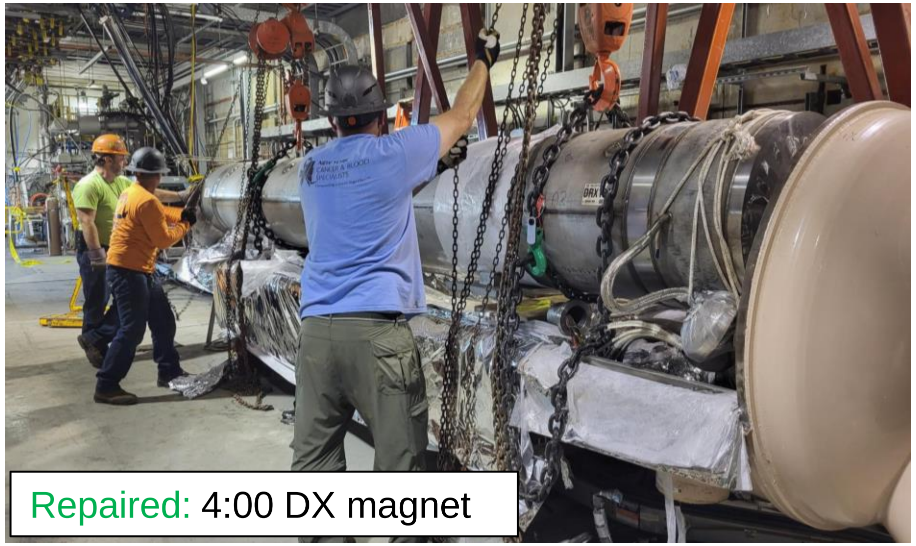


Downstream damage found at 4:00 cable splice joints and in the DX magnet, and later at the B3Q8 diode
8-month recovery effort involving more than 40 people across many disciplines and departments.

Russ Feder,
Chaofeng Mi et al




Repaired: SC splice joint at can #2


Repaired: 4:00 DX magnet


Repaired: SC splice joint at can #3

Status: All repairs completed
RHIC ASE update completed

→ RHIC 4K cooldown starting 15 April 2024

Completing the RHIC Physics Science Mission in FY24 and FY25

FY24 - $p\uparrow + p\uparrow$ and Au+Au at 200 GeV
FY25 - Au+Au at 200 GeV

RHIC Run Scenarios FY24 – FY25 (from LMBB FY25)

Year	Scenario 1 LMBB FY25	Scenario 2 LMBB FY25	Scenario 3 (optimal RHIC Running)
2024	20 cryo-weeks with sPHENIX and STAR $p^{\uparrow}+p^{\uparrow}$ at 200 GeV	20 cryo-weeks with sPHENIX and STAR $p^{\uparrow}+p^{\uparrow}$ at 200 GeV	28 cryo-weeks with sPHENIX and STAR $p^{\uparrow}+p^{\uparrow}$ at 200 GeV
2025	24 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV	28 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV	28 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV

FY24 priority: $p^{\uparrow}+p^{\uparrow}$
FY25 priority: Au+Au

NP Program Advisory Committee report (Sep 2023)

- *The **top priority for Run24** is completing the commissioning of sPHENIX and collecting the high statistics pp dataset that is the necessary reference for all the sPHENIX hard probes Au+Au measurement to come in Run25 and that will at the same time allow STAR to make landmark polarized proton measurements using its new forward instrumentation.*
- *The **top priority in Run25** is collecting the marquee, high statistics, Au+Au data set that is the raison d'etre for sPHENIX, essential for completion of the RHIC science mission, and that will also allow STAR to complete its scientific program.*

FY24: have approved carryover from FY23 of 6 cryo-weeks

budget for DOE-NP was enacted (8 Mar 2024)
guidance for Run-24 (11 Mar 2024): 25 total cryo-weeks

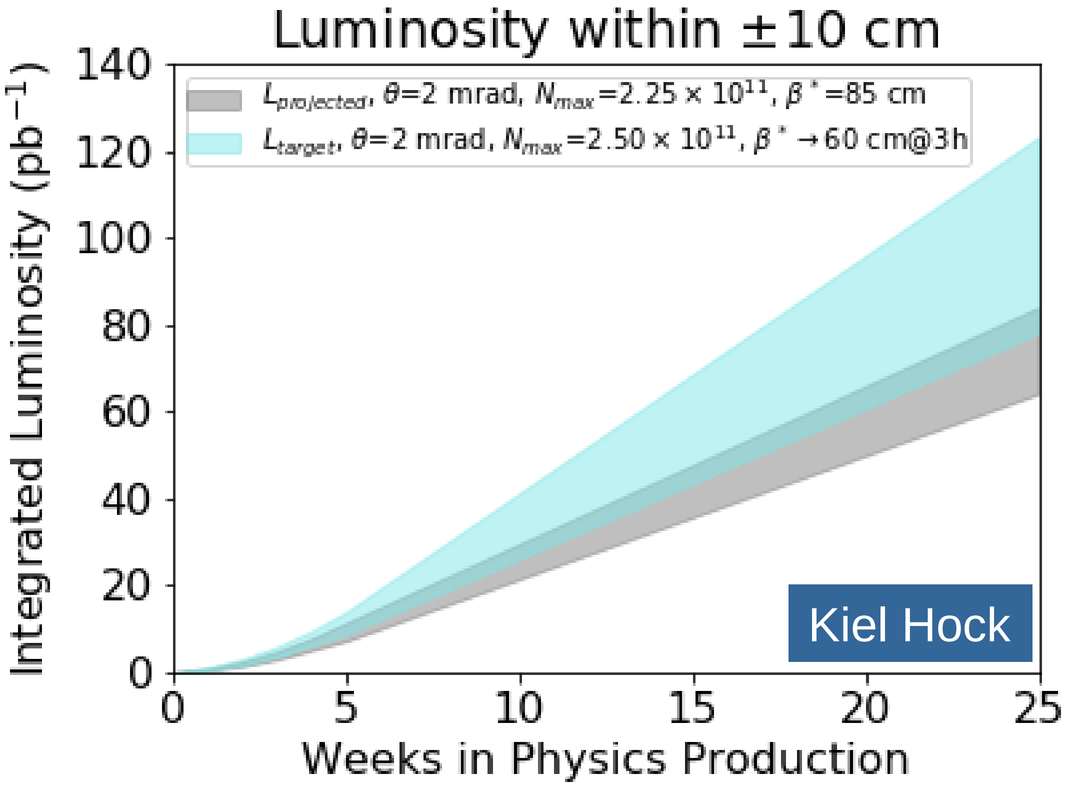
Challenges for RHIC Run-24

Run Coordinator: Kiel Hock
Scheduling Physicist: Caitlin Giorgio
Startup Coordinator: Travis Shrey

sPHENIX goal is 45 pb^{-1} within a narrow ± 10 cm vertex.
Assuming 60% detector availability, this is 75 pb^{-1} delivered luminosity.
This requires a ~35% increase in luminosity relative to the last p↑+p↑ run at 200 GeV c.o.m. (in FY15).

Two main approaches:

- Pre-injector bunch intensity increase to attain $3x10^{11}$ protons per bunch (ppb) in RHIC; i.e. $3.4x10^{11}$ ppb from the AGS.
- RHIC mid-store reduction of beta-star (from 85 cm to 60 cm).



Run 15 minimum and maximum projected shown in grey, with Run24 minimum and maximum projected goal in blue. The Run24 projections include a ramp-up of intensity continuing up to $2.5x10^{11}$ and a β^*squeeze from 85 cm to 60 cm 3 hours into store.

Pre-Injector Developments to attain 3x10^{11} ppb in RHIC

Kiel Hock

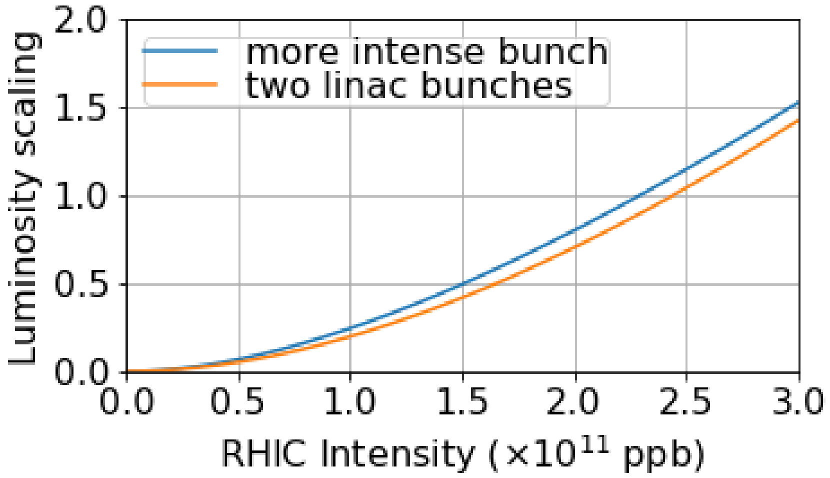
To date, the highest intensity demonstrated at RHIC for polarized protons is 2.4x10^{11} protons/bunch.

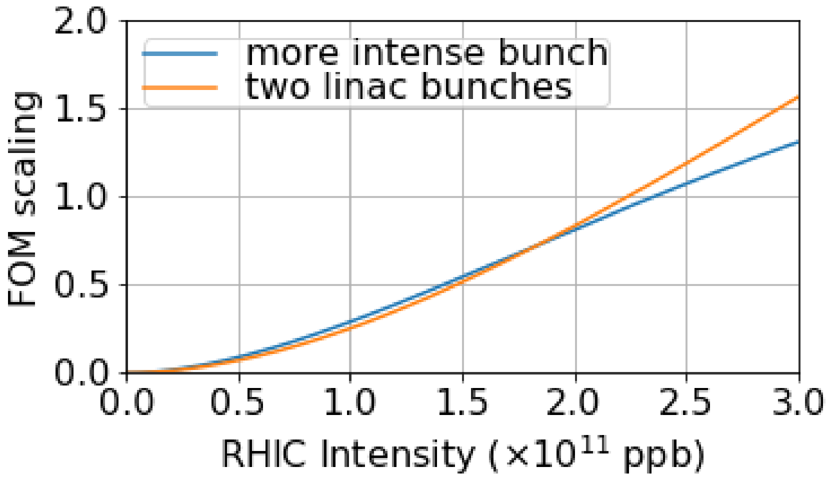
Three setups presently underway in the AGS:

A. Nominal setup (facility re-commissioning)
B. Two LINAC pulses + AGS bunch merge
C. More intense LINAC pulse with AGS Booster bunch split + AGS bunch merge

	Setup A (Nominal)	**Setup B**	**Setup C**
Intensity (x10^{11})	2.1	3.0	3.0
$\varepsilon_{x,y}(\mu m)$	2.11, 2.27	1.96, 2.39	2.51, 2.79
$\varepsilon_s(eVs)$	1.0	2.0	1.2
Polarization	57%	59%	51%
Luminosity Scaling*	1.0	1.43	1.53
FOM Scaling	1.0	1.57	1.31

*Here luminosity scaling is relative to the nominal case.





Although setups B and C have approximately the same luminosity scaling, setup B has an improvement in polarization and a more significant impact on the FOM.

Performance Improvements for FY24, FY25 and Beyond

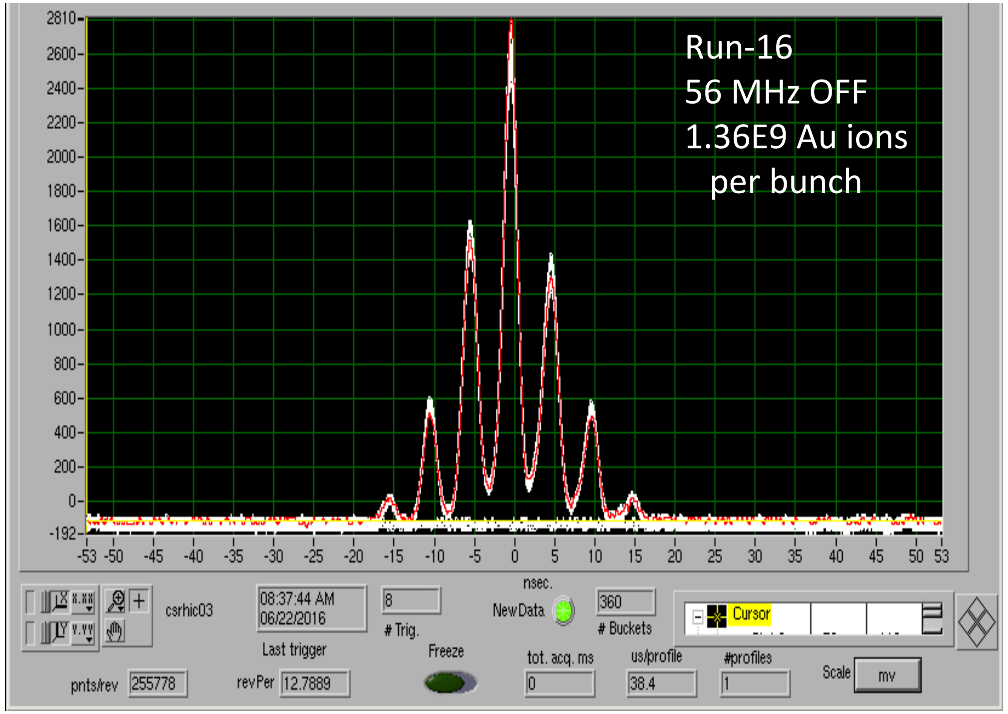
56 MHz cavity – effect on bunch distribution

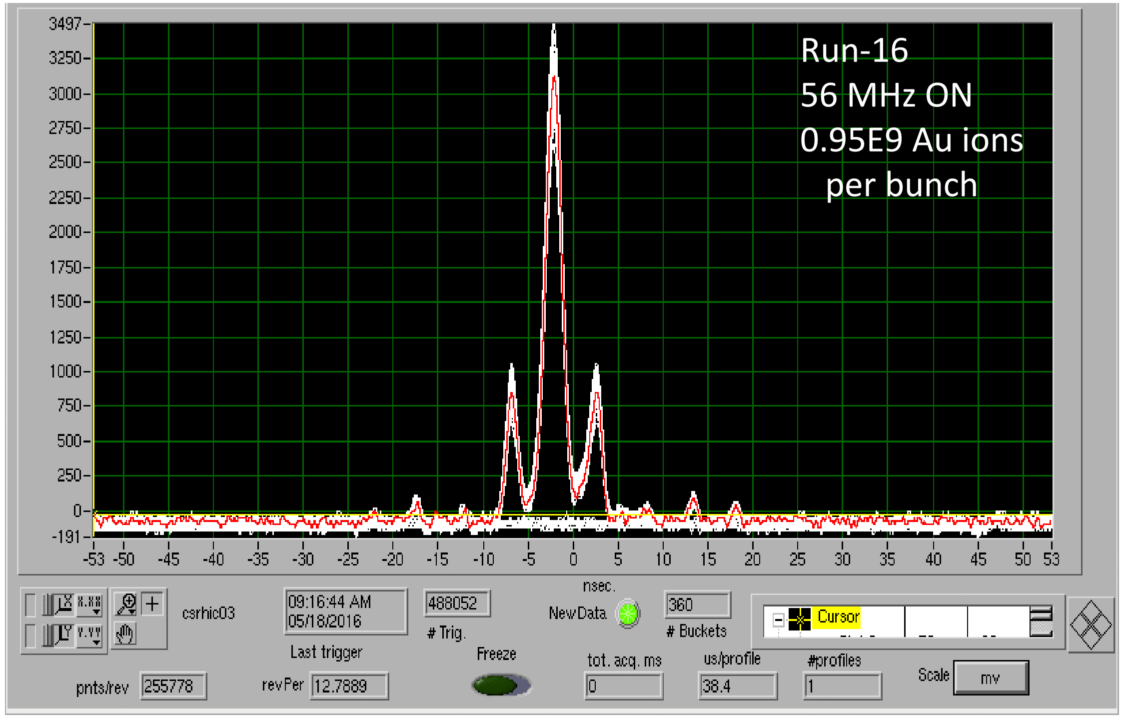
Mike Blaskiewicz, Kevin Smith, Kevin Mernick, Sal Polizzo, Freddy Severino, Qiong Wu, Alex Zaltsman

Increases luminosity in the detector vertex

- increases peak current in primary bunch and reduces and/or eliminates satellite bunches
- enables smaller β^* at the interaction point due to reduced hourglass effect
- expected to reduce detector backgrounds

Demonstrated improvement in longitudinal focusing during run 2016 @900kV (d-Au: Yellow Au WCM)



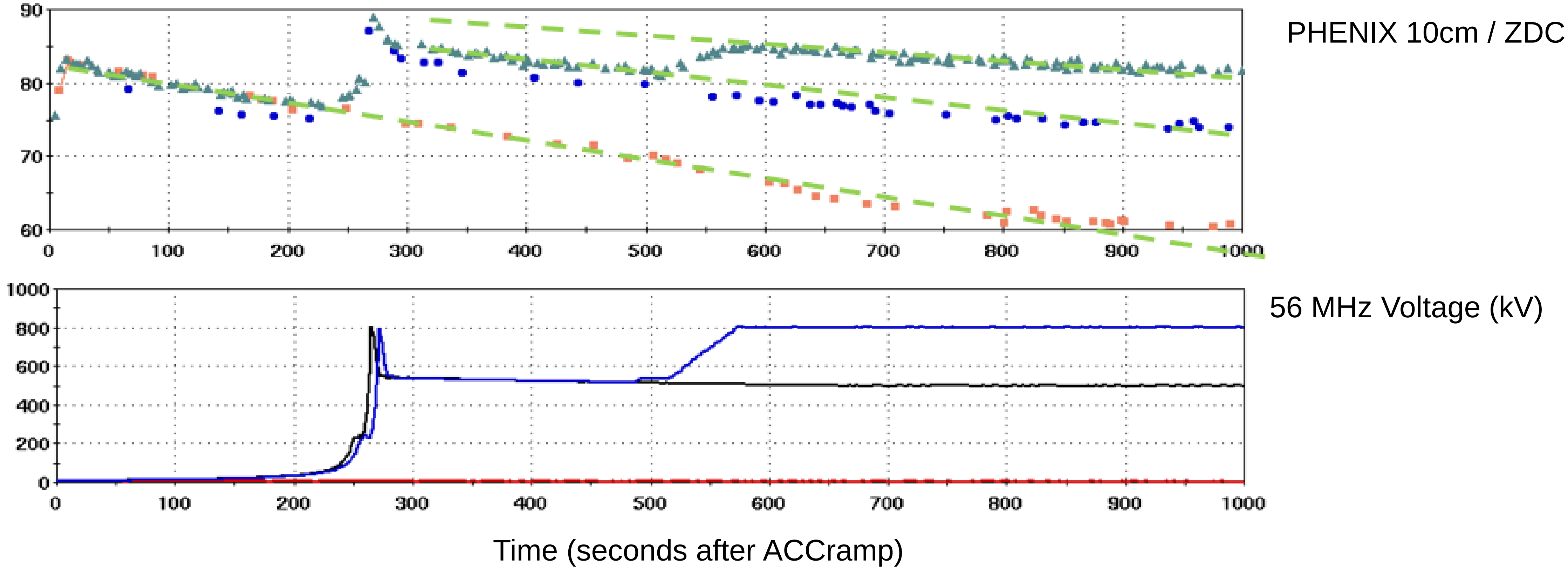


Peak current with 56 MHz SC cavity substantially higher even with lower bunch intensity

56 MHz cavity – effect on luminosity

Mike Blaskiewicz, Kevin Smith, Kevin Mernick, Sal Polizzo, Freddy Severino, Qiong Wu, Alex Zaltsman

Run-16 with 56 MHz SC RF cavity OFF and ON
Blue: 1.95 E9 deuterons / bunch, Yellow: 2.09E9 Au ions/bunch



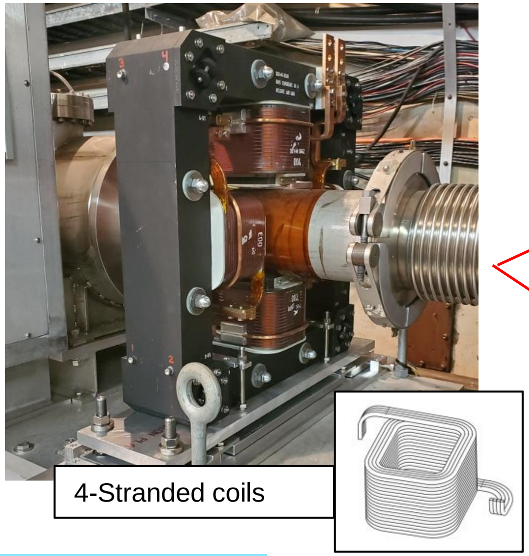
Substantial (>15%) increase in luminosity in sPHENIX (+/- 10 cm) vertex with the 56 MHz cavity

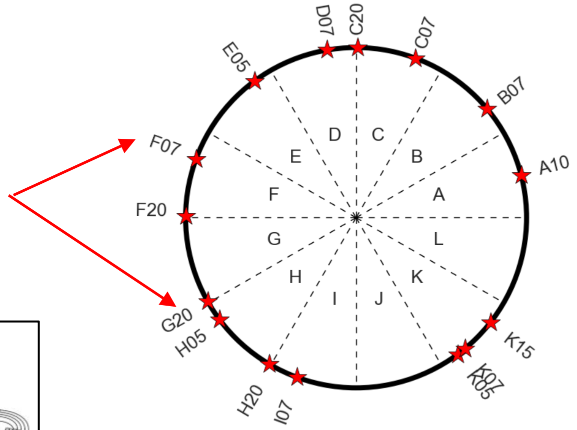
AGS Horizontal Resonance Correction Skew Quadrupoles

Vincent Schoefer

Goal: Full compensation of 82 depolarizing resonances during AGS acceleration using skew quadrupoles

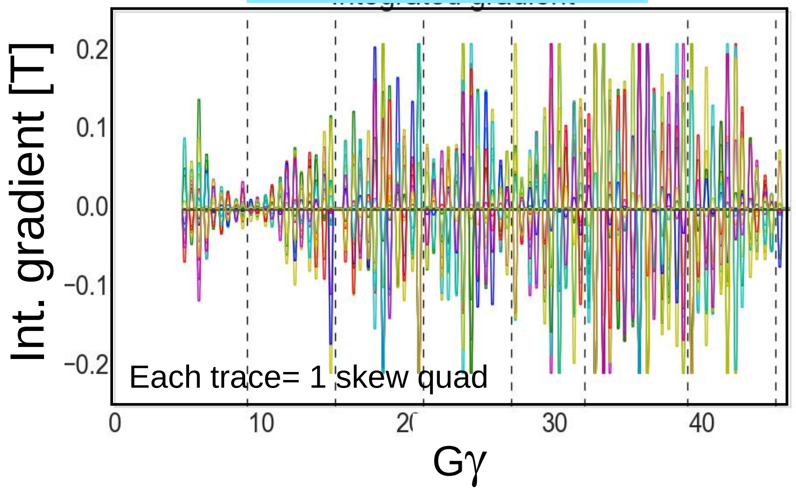
- Expect +8-10% relative increase in peak polarization over present 'tune jump' (>75% polarization at 23 GeV)
- Additional benefit from increased timing tolerance relative to tune jump (1 ms vs 0.1 ms)

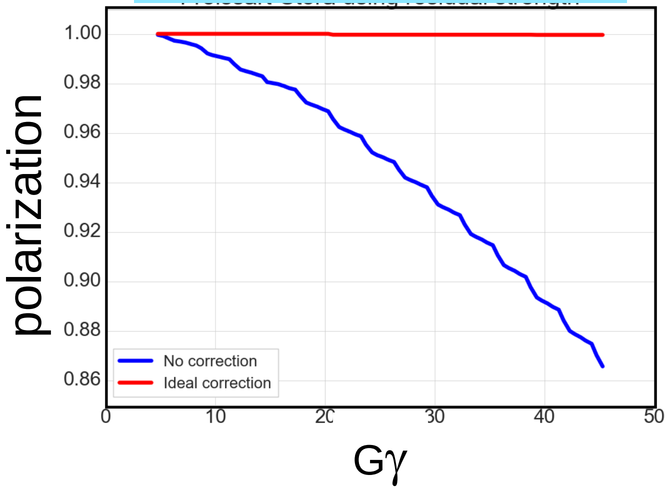




Status and plans:

- All 15 thin, fast-ramping quads installed
- Power supplies: 13 in hand, last to be delivered by 3/29/24
- Future work: Bmad model development to include effects of residual coupling effects





Hardware commissioning underway, commissioning with polarized protons planned prior to RHIC Run-24 start.

Extended EBIS

E. Beebe, J. Ritter, S. Kondrashev

Goals: improvements over EBIS

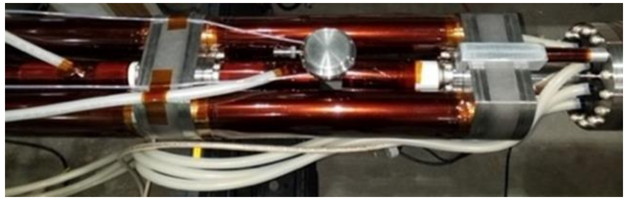
- about 40% more ion intensity
- 2 mA polarized $^3He^{++}$
- provision of ions from H to U

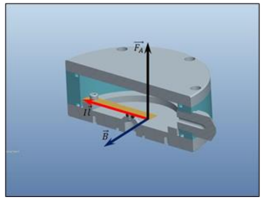
Status:

- operating for NSRL
- demonstrated all ion species including gaseous ions
- commissioned ion injection and extraction into two ion traps, one short and one long trap
- working on higher repetition rate

Extended EBIS key components

Unique gas cell and pump out manifold with a fast Lorentz gas pulse valve





$$d\vec{F_A} = I[d\vec{l}\ \vec{B}]$$

custom linear NEG pumping units in short and long trap regions

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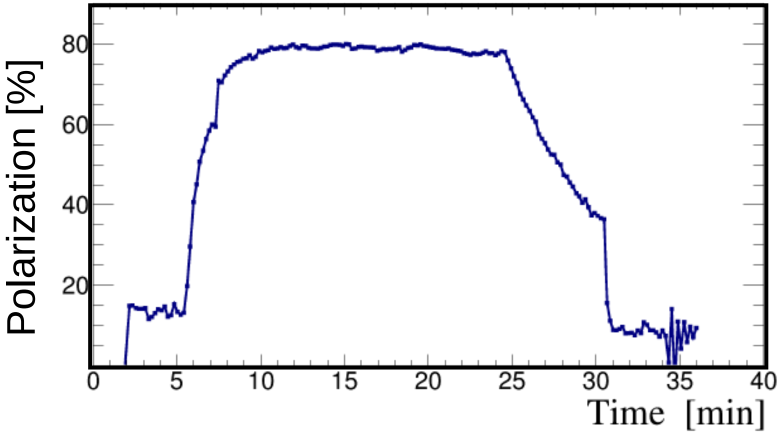
$^{3}He^{++}$ Source for the EIC

R. Milner, A. Zelenski, D. Raparia, G. Atoian, S. Ikeda, S. Kondrashev, N. Wuerfel, C. Ianzano

Goal: Provide polarized $^{3}He^{++}$ beam with 2 mA peak current and polarization > 80%

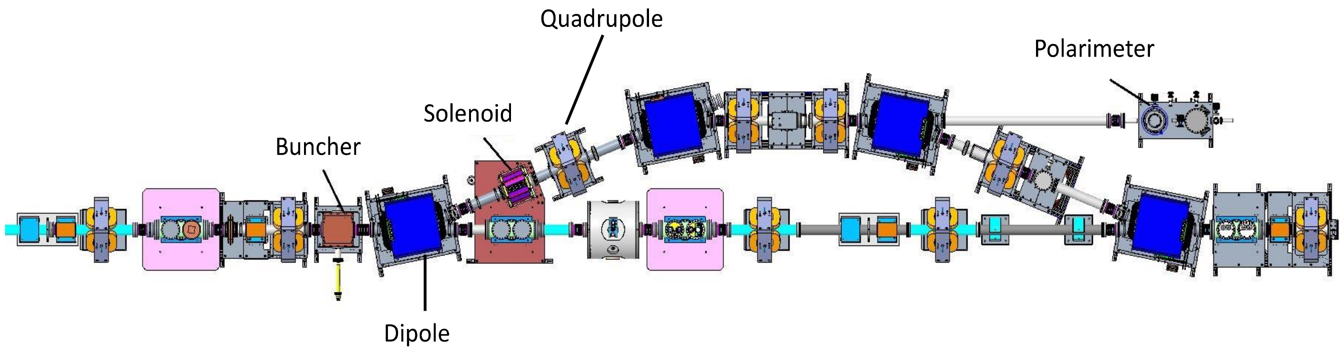
Status

- ^{3}He injection demonstrated (in extended EBIS test lab)
- ^{3}He polarimeter tested in the lab, ready for installation
- achieved >80% polarization in test lab



final source configuration in the test lab

spin rotator chicane (commissioned) and future location of ^{3}He polarimeter



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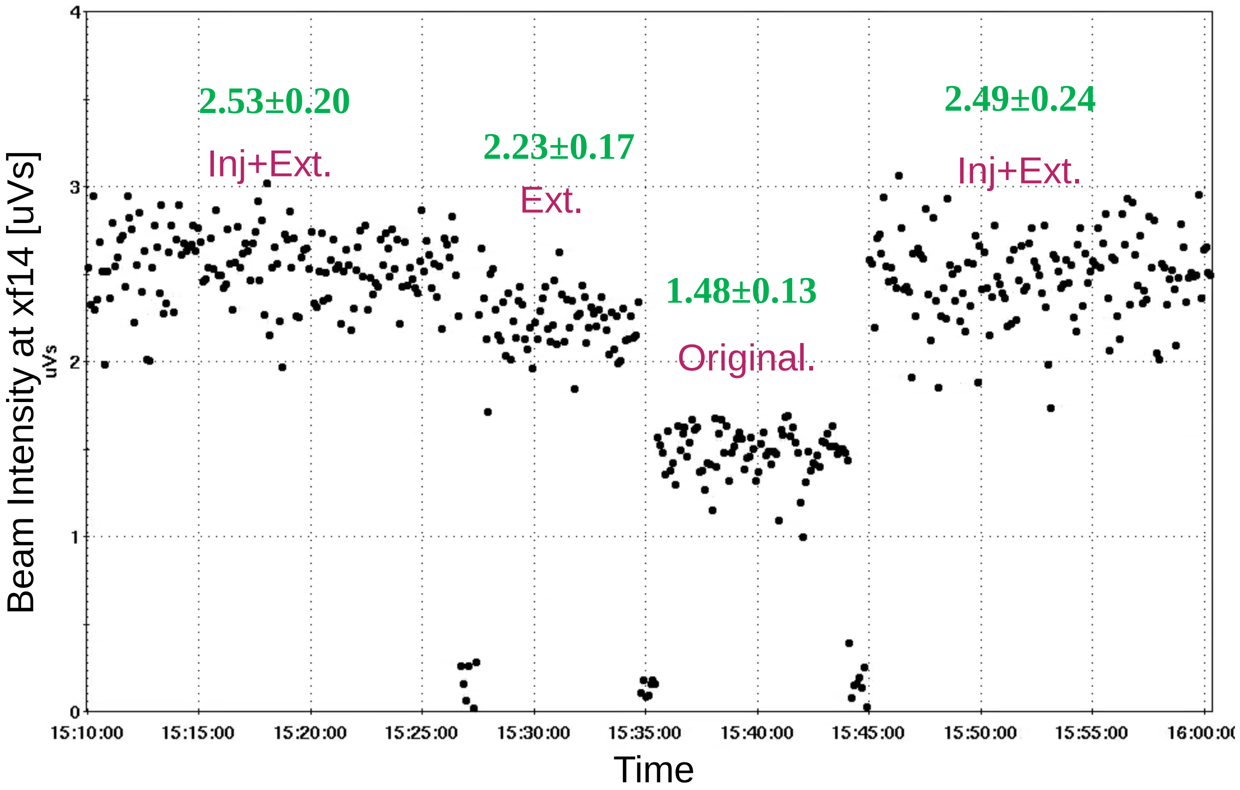
ML Developments: Pre-Injector Intensity Optimization

Xiaofeng Gu



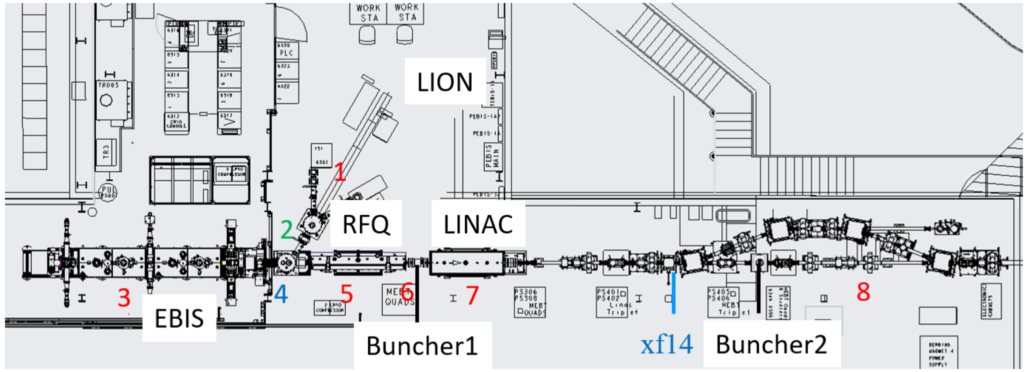


Table 1: A selection of parameters which could have more effects on beam properties

sections	Item	Description	Parameters Number
1	LION	Laser Ion Source	4
2	Injection Line	Electron Beam Ion Source Injection Line	9
3	EBIS	Electron Beam Ion Source	30 – 40
4	EBIS Extraction Line	Electron Beam Ion Source Extraction Line	10
5	RFQ	Radiofrequency Quadrupole Linac	2
6	MEBT	Medium Energy Beam Transport	4
7	Linac	Linear Accelerator	4
8	HEBT	High Energy Beam Transport	17
9	Buncher	High Energy Beam Transport	6

ML (code: GPTune) applied for intensity optimization in (extended) EBIS; achieved a 70% relative increase in intensity measured at the current transformer (xf14) just upstream of the buncher.

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ML Developments: Higher RHIC polarization by Physics-Informed Bayesian Learning

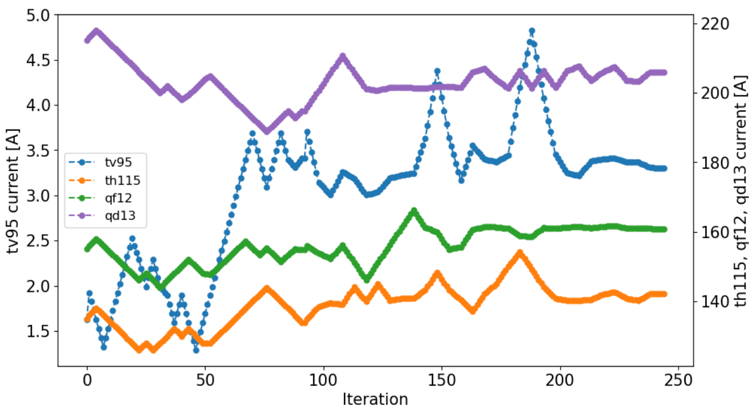
FOA PIs
Georg Hoffstaetter
Kevin Brown

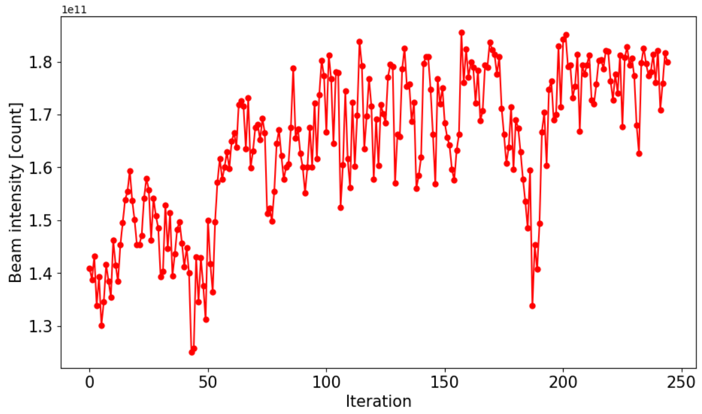
Goal: increase in AGS polarization by 5% (> 20% for P^4 merit) by

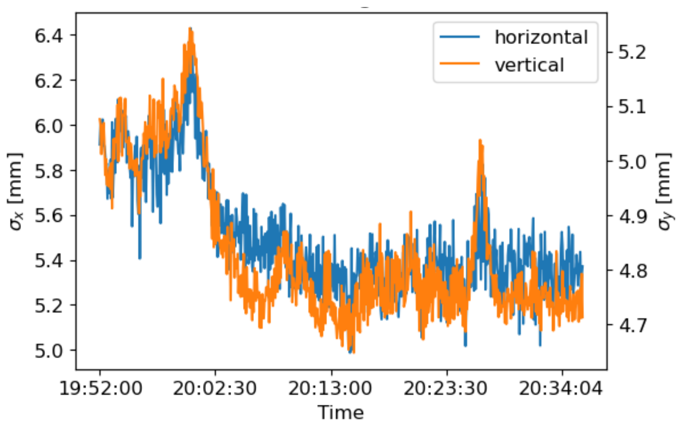
- emittance reduction in Linac-to-Booster (LtB) and Booster-to-AGS (BtA) injection and Booster/AGS optics correction re-bucketing.
- more accurate timing of timed elements, e.g. quad and skew quad jumps.
- reduction of resonance strengths by skew quads in the AGS.

Recent developments (Mar 2024) leveraging improved Bmad models of the LtB, BtA, Booster, and AGS

Lucy Lin







LtB bend & quad training ➔ Intensity increase ➔ reduction in BtA emittances

Increase in AGS Booster intensity and emittance reduction in the BtA using Bayesian Learning in the LtB

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Summary and Outlook

Summary and Outlook

Mission Support and the Long-Range Plans

Achieving recommendations from 2015 and 2023 LRPs for both RHIC operations and the EIC.

Performance of the FY23 RHIC Run

sPHENIX commissioning successfully executed while also delivering beams to STAR; run was challenged by operation during summer months (which will continue).

Completing the RHIC Physics Science Mission in FY24 and FY25

Priorities are $p\uparrow+p\uparrow$ in Run-24 and Au+Au in Run-25 both at 200 GeV c.o.m. energy.

RHIC Run-24 will comprise 25 cryo-weeks including the carryover, RHIC Run-25 schedule is yet TBD.

Performance Improvements

Developments are underway to maximize luminosity in Run-24 and Run-25 and polarization in Run-24 with R&D for the EIC and User Facilities.

While we are grateful for the budget allocation for RHIC operations in FY24, it is less than optimum: effective and efficient use of all beam time (for Physics and APEX) is essential.

Supplementary Material

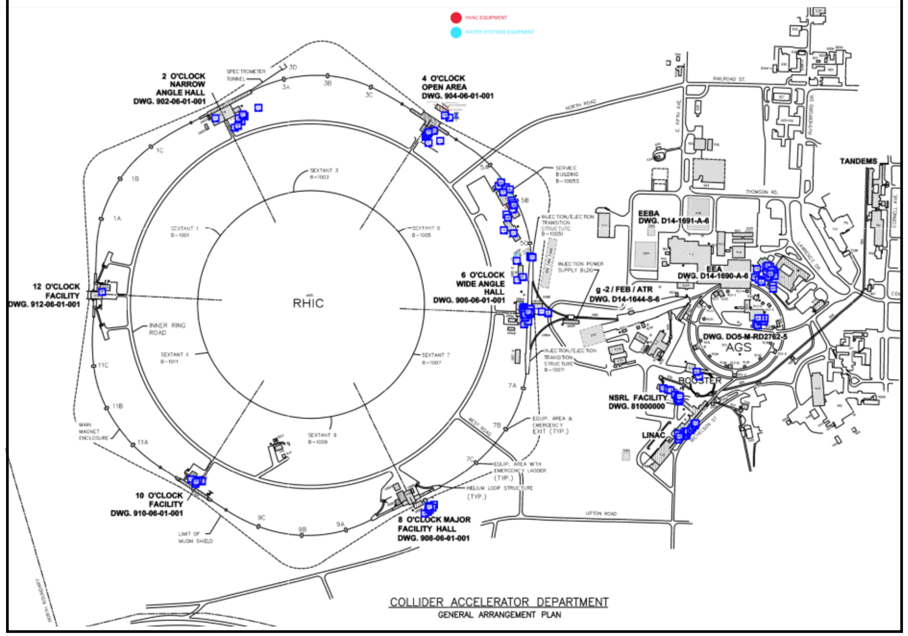
RHIC operations through summer months

David Chan

Remediation measures for RHIC Run-24

- Established dedicated off-hours AC mechanical support (F&O).
- Established service contracts through AC unit manufacturers (Trane and Carrier AC Systems).
- Documenting and tracking preventative maintenance (PM) of all critical AC systems; all critical AC systems and ODH fan PMs completed, all critical water systems heat exchangers cleaned.
- Ductwork modified in all RHIC service buildings to minimize recirculation to PS intake.
- Installed additional new 50 ton AC unit in Bldg. 1004B, spare (50 ton) expected 1 May 2024.
- Portable AC units for deployment as needed:
  - Rentals (May – Sept) : 30, 40, and 60 ton units with generators, 60 ton air-cooled chiller with generator,
  - Procured 10 additional units (of varying capacity, 12 tons and under).
- Procured and received 5 (1.5 and 2 ton) spare split AC units for RHIC alcoves.
- Procuring spare parts for AC systems – 70% received, remainder expected before FY24 RHIC.

Site map for (54) critical AC Units



portable spare AC unit inventory

spare parts inventory

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